New Features of HYCOM

Alan J. Wallcraft

Naval Research Laboratory

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HYCOM 2.2 (I)

- Maintain all features of HYCOM 2.1
  - Orthogonal curvilinear grids
  - Can emulate Z or Sigma or Sigma-Z models
    - It is “Arbitrary Lagrangian-Eulerian”, see: Adcroft and Hallberg, O. Modelling 11 224-233.
  - Explicit support for 1-D and 2-D domains
  - KPP or Kraus-Turner or Mellor-Yamada 2.5 or Price-Weller-Pinkel
  - Rivers as bogused surface precipitation
  - Multiple tracers
  - Off-line one-way nesting
  - Scalability via OpenMP or MPI or both
    - Bit-for-bit multi-cpu reproducibility

HYCOM 2.2 (IIa)

- Alternative scalar advection techniques
  - Provided by Mohamed Iskandarani
  - Donor Cell, FCT (2nd and 4th order), MPDATA
  - FCT2 replaces MPDATA as standard scheme
- Vertical coordinate changes
  - Vertical remapping uses PLM for fixed coordinate layers
  - Thin deep iso-pycnal layers
  - Stability from locally referenced potential density
  - Spatially varying layer target densities
    - Different isopycnal layers in semi-enclosed seas

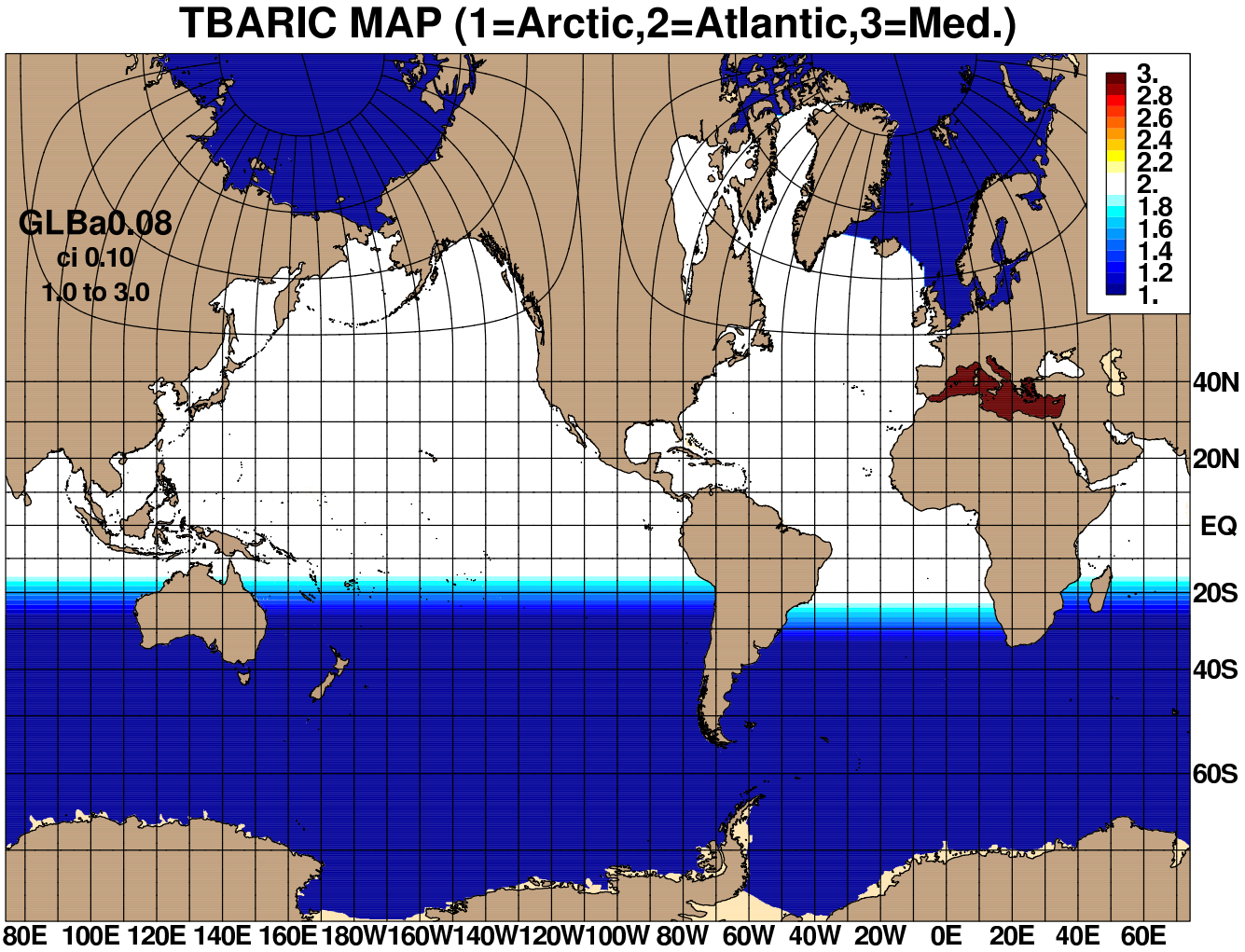
HYCOM 2.2 (IIb)

- Equation of state that is quadratic in salinity
  - HYCOM must “invert” the equation of state
    - tofsig(r,s) and sofsig(r,t)
  - Traditional version is cubic in T and linear in S
    - Finding the root of a cubic is expensive, but exact
    - Linear in S is not accuarate at low salinity
  - Optional version is cubic in T and quadratic in S
    - Coefficents provided by Shan Sun
    - More accurate at low salinity
      - Rivers, Black Sea, Caspian Sea
    - Not much more expensive

HYCOM 2.2 (IIc)

- Special halo exchange for tripole global grid
  - Arctic dipole patch on standard Mercator globe
  - Logically rectangular domain
    - Two halves of top edge “fold” together
    - V-velocity changes sign across the fold
- Improved thermobaricity
  - No single reference state is approriate for the global ocean
    - Hallberg, Ocean Modelling, 8, 279-300
  - Use a linear combination of pressure gradients from two out of three reference states
    - Atlantic (3°C, 35.0 psu)
    - Arctic/Antarctic (0°C, 34.5 psu)
    - Mediterranean (13°C, 38.5 psu)
  - Most locations use just one reference state
    - Linear combinations allow smooth transition between states
      - Do this in shallow water if possible
  - In deep water, constrain the T&S used for thermobaricity to be close to the reference state

1/12° GLOBAL THERMOBARIC REFERENCE STATE



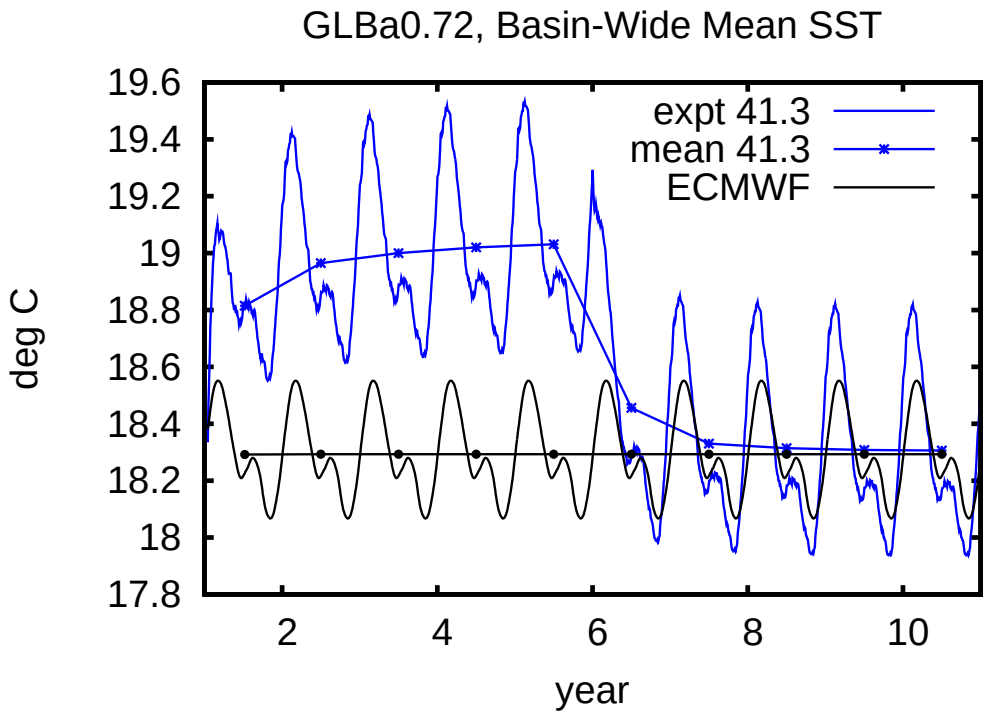
HYCOM 2.2 (IIIa)

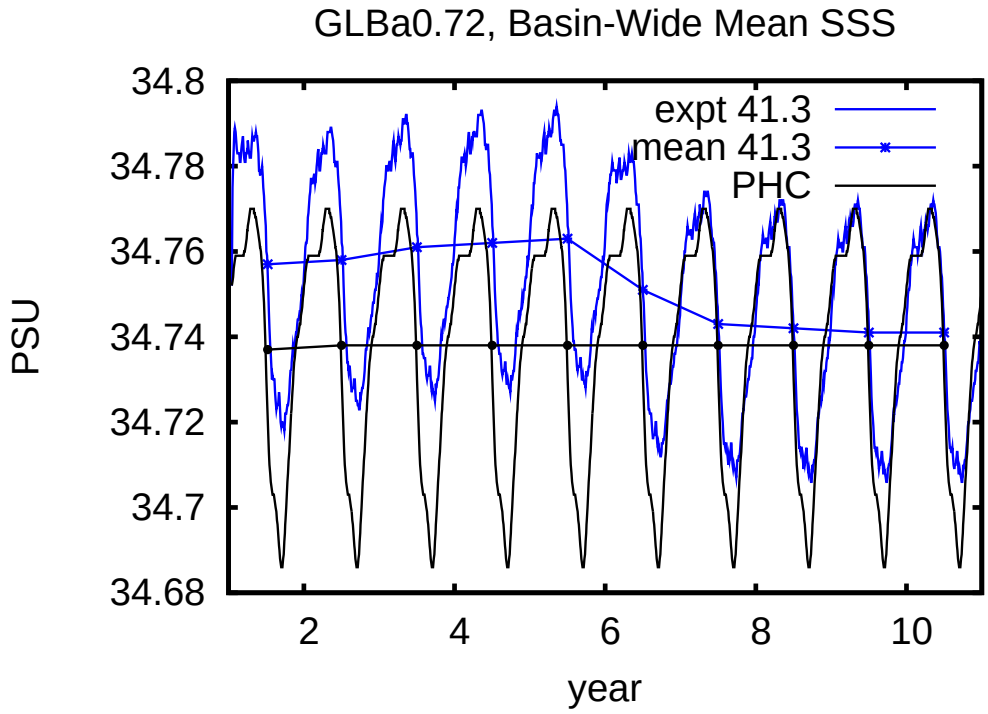
- Mixed layer changes
  - GISS mixed layer model
    - Provided by Armando Howard
  - KPP bottom boundary layer
    - Provided by George Halliwell
  - KPP tuning
- Atmospheric forcing changes
  - Option to input ustar fields
    - Best option for monthly forcing
    - Otherwise calculated from wind stress or speed
  - Can relax to observed SST fields
  - Improved COARE 3.0 bulk exchange coefficients
  - Black-body correction to longwave flux
  - Climatological heat flux offset, $\overline{Q}_c$

$$Q = (Q_{sw} - Q_{lw}) + (Q_l + Q_s) + \overline{Q}_c$$

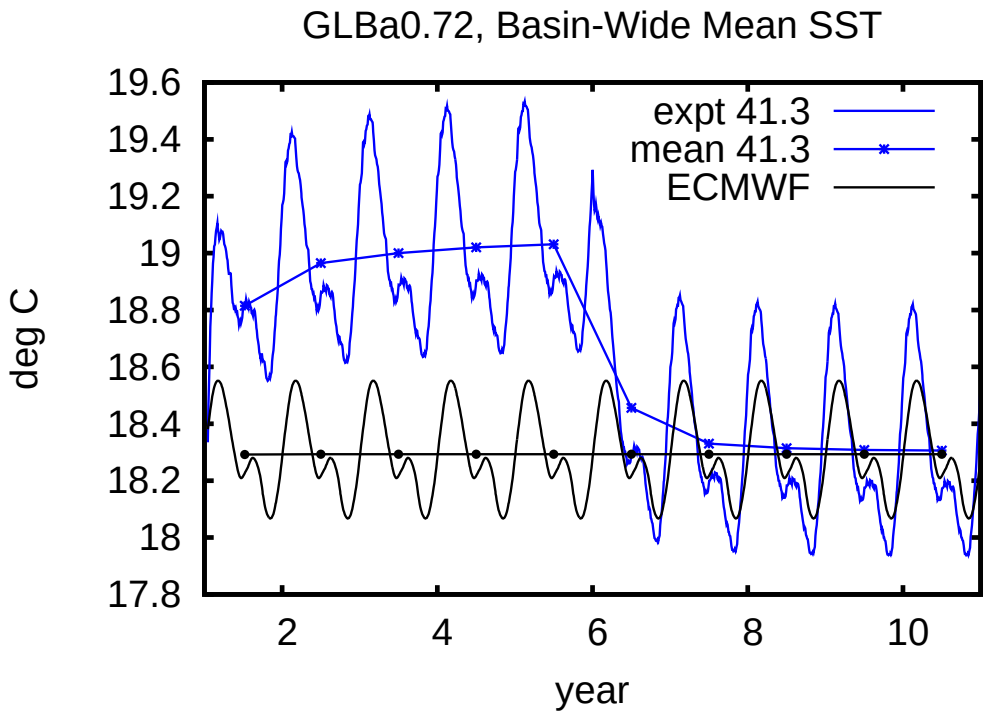
    - $\overline{Q}_c$ is constant in time
      - Typically based on the model's climatological SST error, times (say) -45 $Wm^{-2}/^{\circ}C$

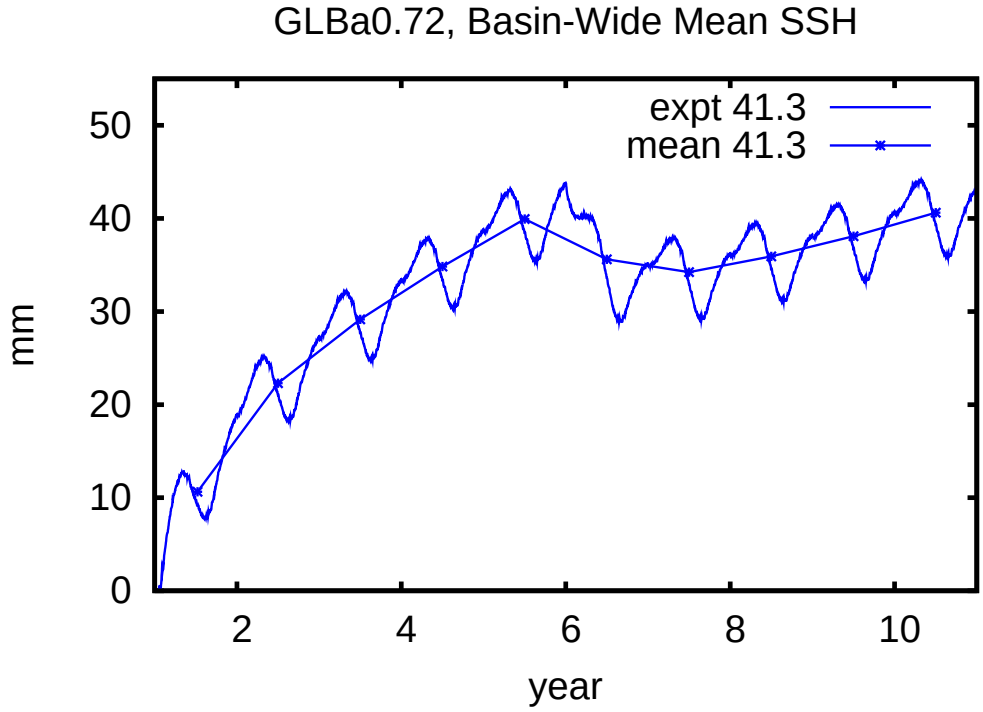
$\overline{Q}_c$ ADDED AFTER FIVE YEARS
GLOBAL MEAN SST and SSS





$\overline{Q}_c$ ADDED AFTER FIVE YEARS
GLOBAL MEAN SST and SSH





HYCOM 2.2 (IIIb)

- Improved support for rivers
  - Still bogused surface precipitation
  - High frequency inter-annual river flow allowed
    - Add it to atmospheric precip, off-line
    - Instead of monthly climatology,
      or in-addition to it (flow anomalies)
  - Better control of low salinity profiles
  - Option for mass (vs salinity) flux
  - Equation of state that is quadratic in salinity
- Tidal forcing
  - Provided by NCEP
  - Body forcing and open boundary forcing
  - Boundry forcing currently for “Flather” ports
    - Extend it to Browning-Kreiss ports and nesting

HYCOM 2.2 (IIIc)

- New diagnostics within HYCOM
  - Time-averaged fields (in archive files)
  - Synthetic instrumentation
    - Provided by George Halliwell
    - 3-D particle tracking
    - surface and constant depth drifters
    - isopycnic drifters
    - fixed instruments and moorings

HYCOM 2.2 (IIId)

- Finer control over energy loan ice model
  - Melting point can be linear in salinity
  - Set ice minimum and maximum thickness
  - Set ice vertical temperature gradient
    - Or get ice surface temperature from T_a
  - Made compatible with coupled sea-ice approach
- Two-way coupling to LANL's CICE sea ice model
  - HYCOM exports:
    - SST, SSS, SSH
    - Surface Currents
    - Available Freeze/Melt Heat Flux
  - CICE exports:
    - Ice Concentration
    - Ice-Ocean Stress
    - Actual Freeze/Melt Heat/Salt/Mass Flux
    - Solar Radiation at Ice Base

HYCOM AND ESMF

- Earth System Modeling Framework
  http://www.esmf.ucar.edu/
  - Superstructure couples components
    - Air/Ocean/Ice/Land
    - Asynchronous I/O component
      - Run “concurent” with model components
  - Infrastructure provides data structures and utilities for building scalable models
- Added a superstructure “cap” to HYCOM
  - Simplifies coupled systems
    - HYCOM coupled to LANL CICE sea-ice
    - Convert atmospheric field processing and the energy-loan ice model into ESMF components
  - Use ESMF for (user-level asynchronous) I/O
  - Interoperate with other ESMF compliant ocean models (e.g. Poseidon, MITgcm, MOM4)
- This initial ESMF support is optional
  - TYPE=esmf instead of TYPE=mpi
- ESMF will eventially required to run HYCOM
  - HYCOM version 3.0

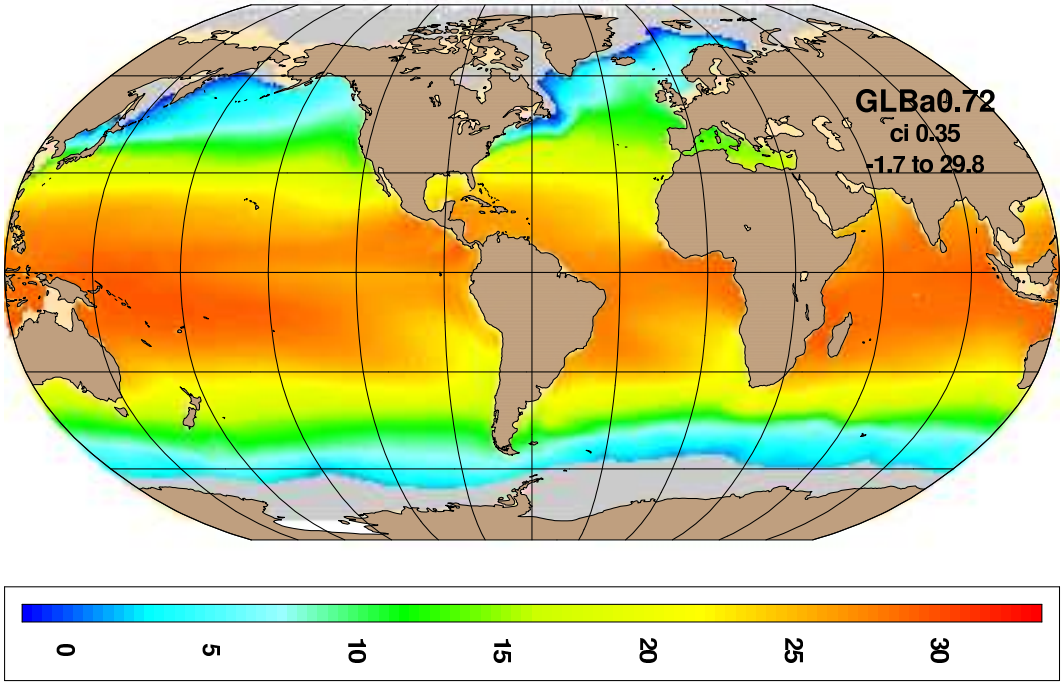
HYCOM 2.2 (IV)

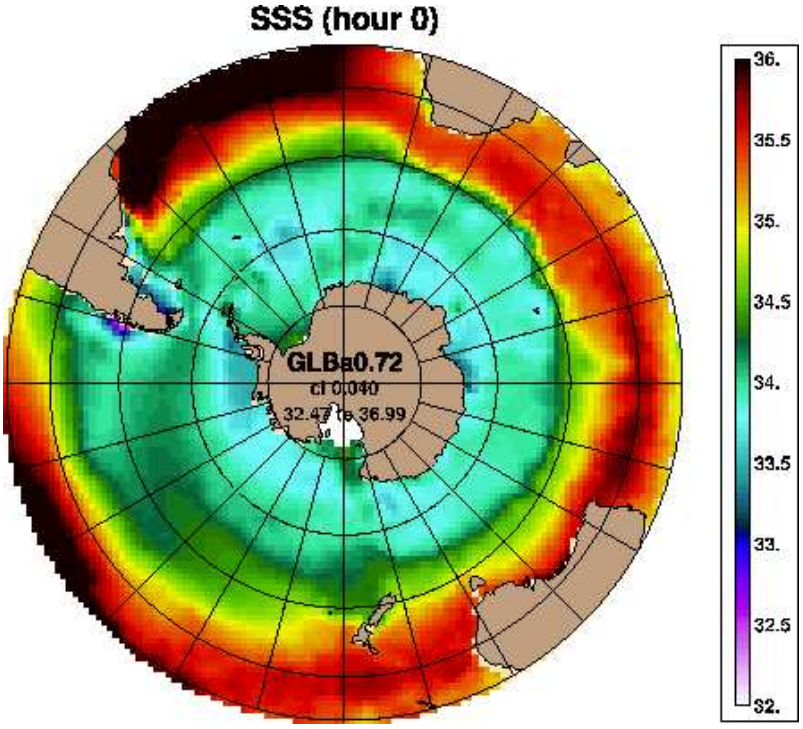
- Climatological nesting now allowed
  - Start from monthly mean outer model archive files
  - Allows nested runs longer than the outer run
    - But with less accurate boundary state
  - Probably only suitable for regional nests
- Nesting no longer requires co-located grids
  - General archive to archive horizontal interpolation (curvilinear)
- Hybrid to fixed vertical grid remapper
  - Allows fixed-coordinate nests inside hybrid coordinate outer domains
    - HYCOM to (fixed-grid) HYCOM
    - HYCOM to NCOM

HYCOM 2.2 (V)

- Enhanced hycomproc and fieldproc
  - NCAR-graphics based
  - Many more color palette options
    - Can read in an arbitrary palette
  - Mark locations, and draw tracks, on plot
  - Plot diffusion coefficients and tracers (hycomproc)
  - Overlay vector and line-contours (fieldproc)
- Added fieldcell
  - Like fieldproc, but for cell-array (vs contouring)
    - Mark locations and draw tracks
    - Overlay line-contours
  - Uses NCAR’s map projections
  - Typically much faster than fieldproc,
    but can leave unfilled cells
  - Option to increase resolution of input (bi-linear interpolation)

ERA-15 SST: Feb





HYCOM 2.2 (VI)

- Diagnostic fields to netCDF and other file formats
  - Archive fields in layer space
    - On p-grid (interpolated velocity)
  - 3-D archive fields interpolated to z-space
    - On p-grid, or
    - Sampled along arbitrary tracks
  - 3-D archive fields sampled on iso-therms
  - Meridional stream-function from (mean) 3-D archive
    - In logical array space (rectilinear grids)
    - Binned to latitude bands (curvilinear grids)
  - Atmospheric forcing input fields
    - Time axis depends on “.b” file format
    - Any “.a” file with the right “.b” file structure can be converted to netCDF
  - Fields binned into lon-lat cells

HYCOM CURVILINEAR GRIDS and NetCDF

- Most basin-scale cases use a Mercator grid
  - 1-D lat & lon axes (rectilinear)
  - Handled well by many netCDF packages
- Global HYCOM's Arctic patch grid is curvilinear
- HYCOM netCDF use the CF-1.0 conventions, which support curvilinear grids
  - If latitude and longitude are 2-D grids
    - 1-D axes are array indexes
    - Longitude and latitude arrays are also in the file and identified as alternative coordinates
- Most netCDF packages are not CF-1.0 aware
  - Bin into uniform lon-lat cells off-line
  - Interpolate to a 1-D latitude and longitude grid off-line
    - General archive to archive horizontal interpolation
- Archive to archive remapper can also be used for standard (non-native) grids
  - MERSEA grid is uniform 1/8°
  - AOMIP grid is rotated uniform 1/2°

CANDIDATE FEATURES FOR HYCOM 2.3

- Stable-code vs new features
  - Released code-base has to be tested and stable
  - New features can be a significant improvement
  - Will add interim releases to web page
    - Features may be removed in next released code
- Fully region-independent
  - Compile once, run on any region and any number of processors
    - Run-time memory allocation
    - Might reduce performance (fewer compiler optimizations available)
  - Needed for full ESMF compliance
- Wetting and Drying
- Diurnal heat flux cycle
- Wind drag coefficient based on model SST
- Support for HYCOM in CCSM
- Enhanced support for ESMF